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ADVANCED COMMAND AND CONTROL ENVIRONMENT (ACCE) INTEGRATION Task Overview

Knowledge Systems Concepts, Inc.

Paul Bell and James M. Marcinkowski

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13. ABSTRACT (Maximum 200 words)
This report summarizes the work conducted under the Advanced Command and Control Environment (ACCE) Integration task. The ACCE is a facility which aids in assessing the operational utility, feasibility, and acceptability of advanced display presentation systems technology to Air Force command and control problems. This task's objective was to provide basic planning and integration support for the evolutionary development and incremental expansion of the ACCE. Advanced display presentation technologies emphasized within the ACCE included three dimensional (3D) stereoscopic display technology utilizing a time-multiplexed liquid crystal stereoscopic shutter (LCSS) system, and volumetric display display technology which presents the visual equivalent of a physical model by projecting a scene onto a vibrating mirror. Under the task, Knowledge Systems Concepts (KSC), Inc. provided overall ACCE program guidance, system design support, and integration support. KSC enhanced the baseline ACCE hardware and software environment, and developed the ACCE Display Evaluation Prototype(ADEP). The ADEP simulates an Air Defense Initiative (ADI) scenario on the advanced 3D display devices resident in the environment.

14. SUBJECT TERMS
Advanced Command and Control Environment (ACCE), ACCE Display Evaluation Prototype (ADEP), Air Defense Initiative (ADI), 3D Stereoscopic Display, 3D Volumetric Display

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Chapter 1

Introduction

1.1 Identification Information

This report is entitled the Advanced Command and Control Environment Integration Final Scientific and Technical Report. It summarizes the accomplishments of an integration and planning effort involving the Rome Laboratory Advanced Command and Control Environment (ACCE) at Griffiss AFB, NY. Knowledge Systems Concepts, Inc. (KSC) has prepared this report under ELIN V009 of Contract F30602-87-D-0085/0020, "Advanced Command and Control Environment Integration", for the Rome Laboratory (formerly Rome Air Development Center) Applied Command and Control Systems Division (COA).

The ACCE's mission is to evaluate advanced display and human machine interface (HMI) technologies for the USAF command and control (C2) community. A primary contract goal was to provide basic planning for the evolutionary development and incremental expansion of the ACCE. In support of this goal, KSC prepared a detailed ACCE Concept of Operations and a variety of documentation collectively referred to as the ACCE *Planning Framework*. This planning framework included: an assessment of the baseline ACCE configuration; a design for an ACCE architecture to support technology development, demonstration, and evaluation; and a roadmap for future ACCE development activities. In conjunction with the preparation of the planning framework, a technology evaluation prototype was developed to showcase the advanced technological components that have already been incorporated in the current ACCE configuration.

1.2 Background

Command and control (C2) is the process and means by which a commander exercises authority and direction over assigned or operationally controlled forces. The commander must quickly assimilate and make sense out of huge volumes of information and then make accurate decisions critical to the battle. Often these decisions are made during times of extreme duress. Automated systems that help commanders to sort through extensive information inputs and quickly evaluate the situation can facilitate the command and control process.

Although bits and pieces of display technology have found their way into C2 systems, many C2 activities are still largely manual. The problem does not appear to be a lack of technology, but lack of a mechanism that leads to the insertion of relevant technology into C2. This was the conclusion of the 1989 Command, Control and Communications (C3) Technology Assessment Conference

sponsored by the Defense Communications Agency (DCA), the Joint Director of Laboratories Technical Panel for C3 and the National Security Industrial Association. Among their findings was the need for further emphasis on the development of technologies to enhance human machine interaction for C2. They also cited the need to develop laboratory facilities to support the technology insertion process.

In response to the 1989 conference findings, Rome Laboratory established the ACCE to assess the operational utility, feasibility and acceptability of advanced display presentations and human machine interface (HMI) technologies for C2.

1.3 Document Organization

This report is organized into three volumes: **Volume I, ACCE Task Overview; Volume II, ACCE Concept of Operations; Volume III, ACCE Planning Framework**. These three volumes represent a complete collection of the major documentation developed during the course of the task. As such, they include a comprehensive summary of the work performed under the ACCE Task, and provide recommended guidelines for future ACCE activities.

Volume I, ACCE Task Overview, contains three chapters and five appendices. *Chapter 1* provides report identification and background information for this Final Technical Report. *Chapter 2* summarizes the ACCE Task and highlights the major accomplishments. *Chapter 3* discusses the conclusions that can be drawn from task activities, and provides specific recommendations regarding future ACCE activities. *Appendix A* describes the operation of a source code library data base that was developed during this effort. This automated data base is used to store, manage, and retrieve the extensive documentation that describes the prototype's source code. *Appendix B* lists the commercial-off-the-shelf (COTS) software manuals that were delivered to Rome Laboratory under this task. *Appendix C* defines the various acronyms used in <u>all three</u> volumes; however, Volumes II and III each retain their own acronym lists to facilitate separate use of these two volumes.

Volume II of this report contains the complete ACCE Concept of Operations document. This document was developed early in the task and formally defines what the ACCE is, what its objectives are, how it will be used, and by whom it will be used.

Volume III contains the complete ACCE Planning Framework document. This is a multi-faceted document. It describes the ACCE baseline environment, and provides the results of an assessment of this baseline in terms of the ability of the initial ACCE configuration to meet the goals set forth in the ACCE CONOPS. Capabilities and shortfalls are provided in the assessment. Next, there is a discussion of USAF open system architecture guidelines and a description of the ACCE architecture that was developed using these guidelines. There is also a description of the prototype that was developed to support the demonstration of advanced display and HMI

technology. Recommendations are provided to help guide future ACCE growth. These recommendations include a development roadmap that lists proposed future ACCE development efforts and suggests priorities and timelines. Finally, Volume III provides general guidelines for ACCE configuration management.

1.4 Contract Data Requirements

This Final Technical Report (FTR) satisfies several Contract Data Requirements List (CDRL) Item requirements. Figure 1.4-1 lists the pertinent CDRL item numbers and titles, and identifies the FTR volume number that satisfies the CDRL requirements.

CDRL Item	CDRL Title	Satisfied in FTR Volume
V002	Planning Framework	Volume III
V003	Concept of Operations	Volume II
V004	ACCE Architecture	Volume III, Chapters 3 and 4
V005	Baseline Assessment	Volume III, Chapter 2
V006	Development Plan	Volume III, Chapter 5
V007	Commercial-off-the-Shelf Manuals	Volume I, Appendix B
V009	Final Technical Report	Volumes I, II and III

Applicable CDRL Items
Figure 1.4-1

1.5 Other Documents Delivered

The following documents were also delivered under ACCE Integration task:

1. *ACCE Display Evaluation Prototype User Manual*: This user manual contains instructions on how to use the prototype that was developed during this task. These instructions describe how to start and operate the prototype, and detail the many user initiated functions that can be executed during a C2 demonstration.

2. *ACCE Display Evaluation Prototype Source Code Documentation*: This report documents the computer system aspects of the prototype by describing the files and functions that comprise the software source code. This documentation is provided to facilitate reuse of the software in future ACCE development efforts.

Chapter 2

Summary of the ACCE Integration Task

2.1 Introduction

This chapter summarizes the ACCE Integration task activities. Each section records the results of a separate contract activity or sub-task. A copy of the key documents referenced in each section are included in their entirety either as an appendix to this volume, or as part of Volumes II and III of this report.

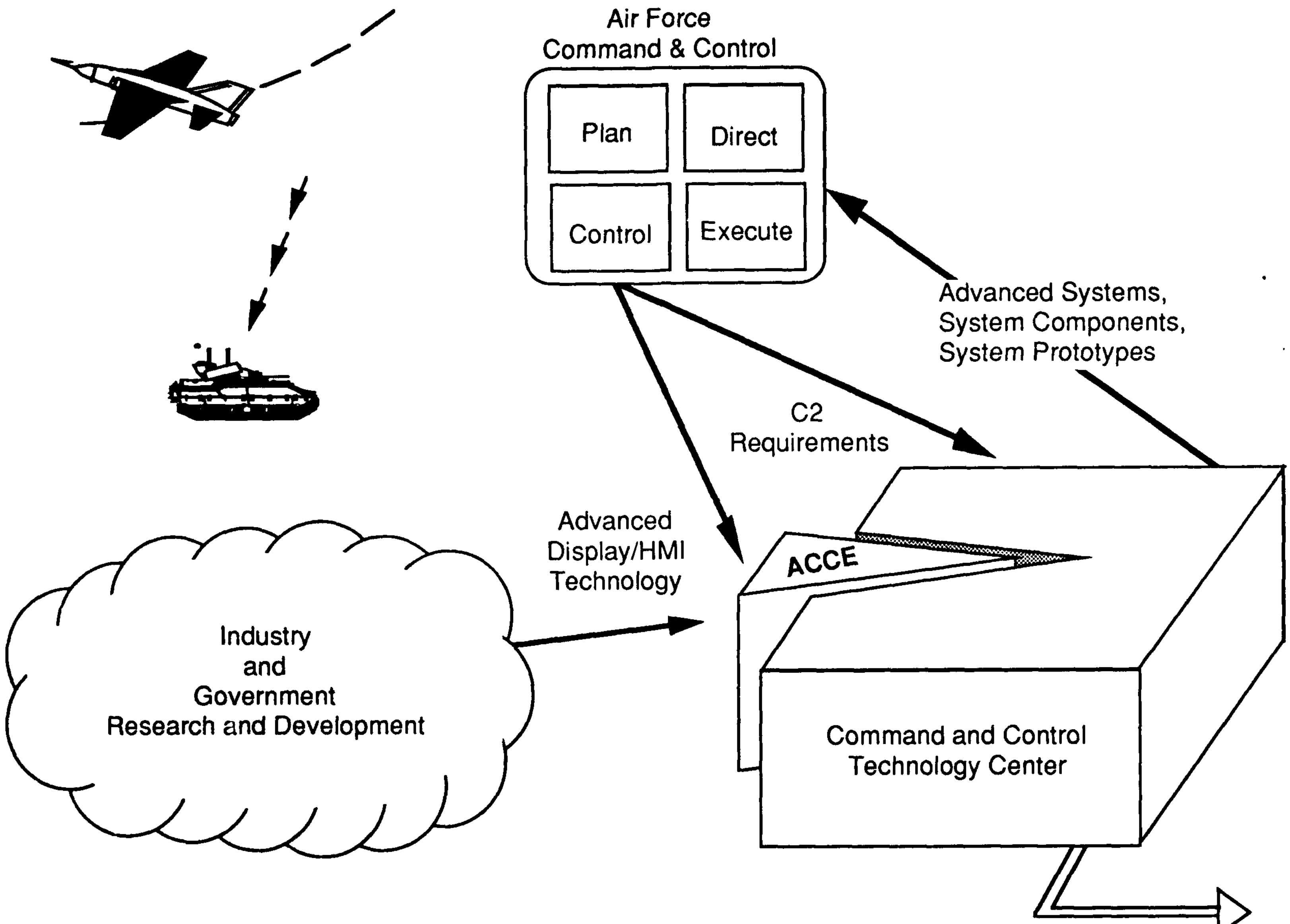
2.2 ACCE Concept of Operations

Preparing the ACCE Concept of Operations (CONOPS) was a major activity. The CONOPS formally identifies the objectives and goals of the ACCE, defines the various types of users and interfaces of the ACCE, and develops a task flow that will allow ACCE users to meet the cited goals. The complete ACCE Concept of Operations document is included as Volume II of this report.

2.2.1 ACCE Program Objectives

The primary objective of the ACCE is to implement a testbed laboratory environment to apply, evaluate, showcase and exploit advanced display and HMI technologies that have the potential to significantly enhance next generation C2 systems. The testbed will be structured to provide a rapidly reconfigurable workbench-like environment where candidate technologies may be evaluated by engineers and users based on selected C2 requirements. Although certain operating conditions within the laboratory may be simulated, they will be realistic enough to conduct a rigorous behavioral analysis of the technology. Significantly, the ACCE concept provides for technology evaluation prior to expensive integration of the technology into advanced development models. Strengths and weaknesses can be identified and engineering modifications recommended. Once the ACCE engineers establish the viability of a technology, C2 system developers may tailor the technology to meet specific C2 applications. This approach not only results in a better product, but it is cost effective since the utility of the technology will be determined before a substantial system integration investment is made.

Figure 2.2-1 illustrates a high level view of the ACCE concept. It shows how the ACCE fits into the total research and development picture as an integral part of the Command and Control Technology Center (C2TC). The C2TC is a Rome Laboratory computer-based facility where users



ACCE Concept
Figure 2.2-1

evaluate Command and Control system level capabilities using realistic encounters with opposing forces. The C2TC examines a number of different technologies such as expert systems, correlation and fusion, and simulation. The C2TC staff demonstrates these advanced technologies to potential users, and those that satisfy requirements are integrated into C2 systems. From the C2TC, advanced systems, system components, and system prototypes are transitioned into the operational Air Force C2 environment.

The ACCE differs from the C2TC in several respects. *First*, the ACCE has a more specific charter. It exclusively supports the analysis and evaluation of advanced presentation and HMI technologies. *Second*, with a narrower scope, it will only focus on bringing technology to bear on C2 HMI and display problems. The C2TC, on the other hand, examines a wider range of technologies to solve their wider range of problems. Thus, the ACCE will provide a laboratory facility complete with equipment, resource libraries, a support infrastructure, operational procedures and a development strategy specifically for applying state-of-the-art interface technology to C2.

The ACCE and C2TC will work in concert to address the technological needs of the C2 community. For example, a program in the C2TC might generate a requirement for a display technique that is beyond the contract scope of that particular program. ACCE engineers could then apply their resources to the problem to develop a candidate solution. Conversely, HMI researchers in the ACCE might identify potential solutions for problems that need the total system capability of the C2TC to confirm their operational worth. Additionally, C2TC or other Rome Laboratory programs can draw upon the ACCE repository of previously evaluated advanced interface technology. Therefore, instead of multiple projects redundantly evaluating the same HMI technique, they may each tap the ACCE for proven technology that meets their requirements.

2.2.2 ACCE Users

Rome Laboratory will employ the ACCE to support diverse categories of users involved in display and presentation technology activities. These include the following: research and development engineers, Rome Laboratory management, and operational USAF C2 personnel.

The ACCE will directly support the efforts of Rome Laboratory research and development engineers and contractors. These researchers will perform experimentation within the ACCE to meet the following goals:

- To provide improvements in information presentation and HMI technology to the C2 community.

- To refine promising information presentation and HMI technology and apply it to a specific C2 user requirement.

- To demonstrate to the end user C2 community advances in information presentation and HMI technology within the C2 context.

- To identify and delineate ACCE-related technology requirements for pertinent development efforts.

- To determine the technical feasibility of incorporating ACCE-related technology into specific programs, given user requirements, budget, and schedule constraints.

- To introduce systems development contractors to the advanced information presentation and HMI technologies that are available at Rome Laboratory so they can be incorporated in C2 systems development efforts.

- To provide recommendations to Rome Laboratory senior managers concerning those technologies that should receive the highest acquisition priority.

Rome Laboratory management personnel are also potential users of the ACCE. Rome Laboratory managers will be more interested in reviewing ACCE demonstrations to support their decision-making tasks regarding issues such as:

- Identifying those promising ACCE-related technologies that should receive funding priority.

- Identifying opportunities to transfer useful ACCE-related technologies to other R&D efforts.

- Establishing R&D efforts to support the transition of successful 6.1 and 6.2 ACCE-related technologies to capabilities that can be incorporated in C2 systems.

Finally, users from the Air Force C2 community should be included in the ACCE to bring operational relevance to the ACCE program; operational relevance is a primary driver for any ACCE activities. Air Force C2 user's primary goal will be to determine whether the technology they see in the ACCE will help them do their jobs more efficiently and increase productivity. Given a favorable outcome from the ACCE demonstrations, these users will be concerned with any impact the insertion of ACCE-related technology will have on their systems and organization.

2.2.3 ACCE Interfaces

The ACCE must establish effective interfaces with the potential users cited above to ensure that substantive inputs from different viewpoints are fully exploited. The ACCE has a requirement to interface with outside agencies such as university consortia to obtain details on new technology developments. Four primary types of information must be obtained and shared across the interfaces:

1. **Requirements**: The Air Force C2 community must provide their requirements to the ACCE, C2TC and other Rome Laboratory components. These requirements include: user interface items - directed to the ACCE; system items - directed to the C2 Directorate engineering staff and project managers; and program items - directed to Rome Laboratory upper management.

2. **Knowledge**: Rome Laboratory directorates and research facilities must share knowledge concerning what has been learned in their experiments about implementing HMI and display technologies. Knowledge can be transformed into expertise, but its value is limited unless it can be accessed by others.

3. **Technology**: Information concerning the capabilities of new technology needs to be recorded, assessed and distributed to others for review.

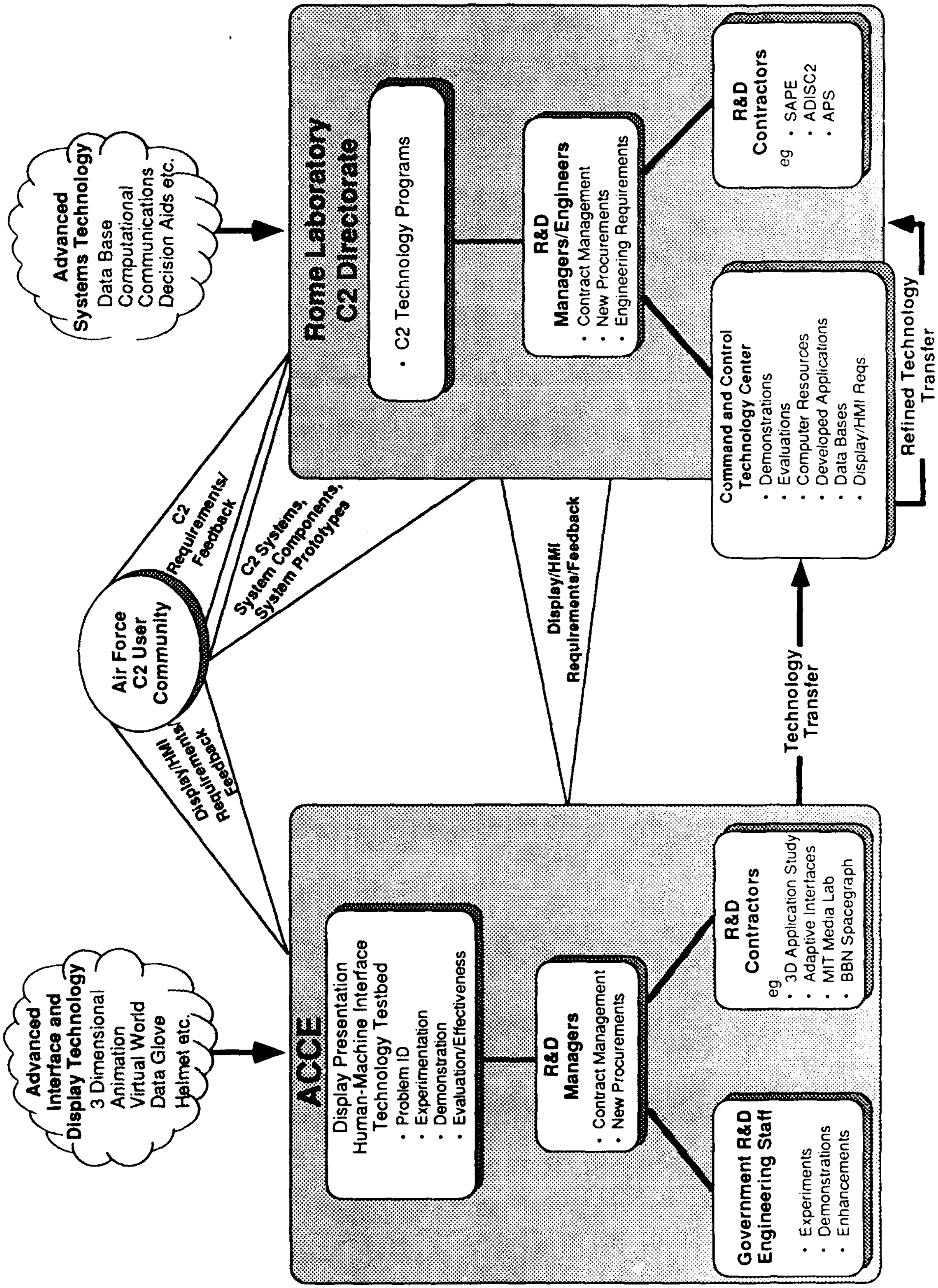
4. **Resources**: Whether the resource is hardware, software, or data, these types of assets need to be pooled and shared among the ACCE and other Rome Laboratory components. This could translate into secure communication links being established among the various laboratory components for selected experiments.

This ACCE interface concept is illustrated in Figure 2.2-2. The following paragraphs expand upon this concept and explain the roles and interaction among the various components.

A key component of the ACCE interface concept involves interfacing to the Air Force C2 user community. It is through this interface that C2 operational requirements are obtained that will give the ACCE's prototypes operational relevance. Feedback will be obtained from these users regarding recommendations on how to improve the demonstrated prototypes and the technologies that they showcase to make them more operationally relevant.

An interface to sources of advanced display and presentation technology is critical to keeping the ACCE technologically current. The ACCE must develop a systematic way to monitor advancements in display and presentation technology made in the commercial, government and academic worlds. Promising technologies need to then be integrated via this interface into the ACCE for further demonstration and evaluation.

The association between activities conducted within the ACCE and those conducted by the Rome Laboratory Command and Control Directorate (CO) is a natural one that needs to be supported by an interface. As depicted in Figure 2.2-2, the ACCE and CO will concurrently conduct R&D. Many CO efforts are subtasks of a project plan formulated to fulfill long-term objectives. Other CO efforts focus on developing complete systems that ultimately will support C2 end users. CO's technological areas of interest include data bases, communications, system development tools, computer hardware and software, and data processing methodologies. CO refines these new technologies and integrates them into advanced development models and



ACCE Interface Concept
Figure 2.2-2

prototypes. Current C2 systems include applications such as battle management decision aids and battlefield activity simulators. Besides developing fully functional systems, some CO efforts concentrate on refining a particular high payoff technology to a point where it may be integrated into a variety of C2 applications. Natural language processing, distributed data base management, or data fusion algorithms are examples of these types of technologies. The establishment of the ACCE, with its display and presentation technology charter, will allow CO program managers to concentrate on the other development challenges.

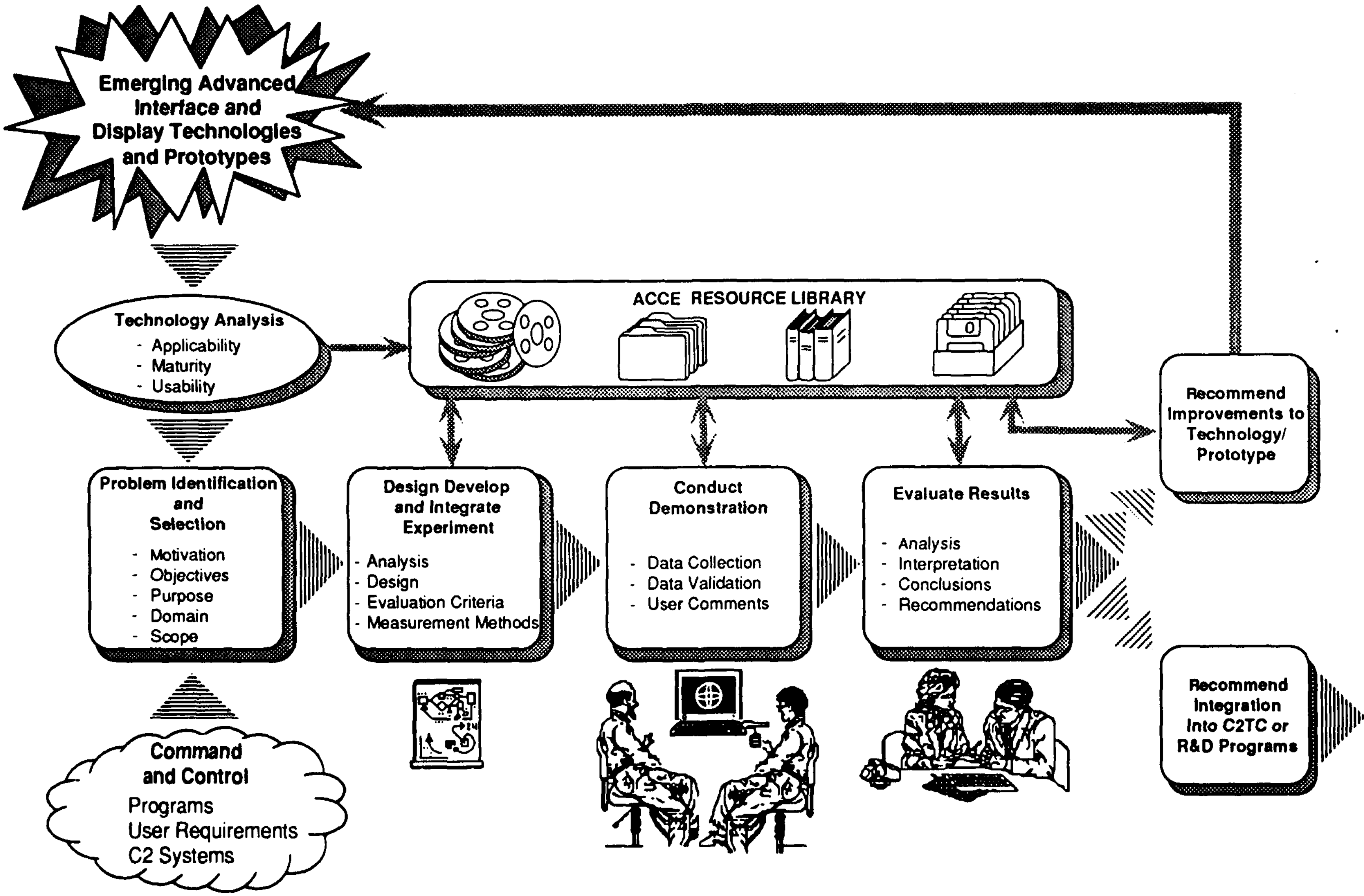
The ACCE's primary interface to CO will be via the C2TC, since the ACCE is physically located within the C2TC. Second, a central facility such as the C2TC, that has the charter to aid C2 technology transfer, is the logical interface choice. While the ACCE may develop experiments to show the application of a specific display and presentation technology, the C2TC will have the capability to take that particular technology and integrate it into a future specific C2 application. Moreover, in the C2TC setting, further experimentation and analysis can be conducted to assess technological usefulness. For example, questions may be answered concerning the impact of the device on the performance of other system functions. C2TC experiments may suggest engineering modifications to the technology that in turn would be carried out in the ACCE.

2.2.4 ACCE Task Flow

The ACCE will support the previously described users in their assessment of the utility, feasibility, and acceptability of advanced information presentation technology applied to Air Force C2 problems. This process is depicted in the ACCE Task Flow Concept graphic, Figure 2.2-3.

ACCE problem identification and selection is the first task in the process and involves identifying a C2 problem that ACCE developers believe can be solved through experiments involving the application of advanced display and presentation technology. Once the C2 problem has been identified and potentially suitable technology to solve the problem has been selected, an experiment must be devised to gauge the effectiveness of the technology. Following design and development, the demonstration phase involves executing the experiment. The major intent of a demonstration is to showcase the innovative application of an advanced display/presentation or HMI technology to a particular C2 problem. Evaluation will then be performed. The purpose of evaluation is to decide whether the specified C2 requirements or characteristics are satisfied by the technology under test. The primary criterion should be how well the C2 system hardware or software supports the commander and battle staff decision process.

The resource library is shown in the figure as a repository of software, data and R&D evaluation results. All tasks interface to the ACCE resource library to preclude redundant development and to enforce the idea of reusability.



ACCE Task Flow Concept
Figure 2.2-3

2.3 ACCE Planning Framework

This section highlights some of the major accomplishments of the ACCE Planning Framework activity that was performed during this task. This activity began with the examination of the ACCE baseline configuration, a configuration that was already in-place at the start of this task. The capabilities of this baseline configuration to satisfy the goals set forth in the ACCE CONOPS were assessed. Next, the USAF Open System Architecture concept was examined, and specific open system architecture recommendations for the future ACCE were derived. A design for an ACCE architecture and prototype was then developed. The design is based on recommendations from the ACCE baseline assessment, as well as architecture guidelines resulting from our examination of the USAF Open System Architecture concept. The design that was implemented under this effort, also provides structure for future ACCE development activities.

A development plan to incrementally expand the ACCE in the future was then developed. This plan included a time phased development roadmap containing proposed implementation tasks and major milestones. Finally, general recommendations were developed for ACCE configuration management. These recommendations address the areas of configuration control, status accounting, and documentation.

The complete document that details the entire ACCE Planning Framework activity is included as Volume III of this report. Selected extracts from Volume III are provided below.

2.3.1 Baseline Assessment

The baseline ACCE configuration available at the start of the task was comprised of two primary systems. These systems were the Silicon Graphics workstation interfaced to a Stereographics Z-Screen display, and a Z-248 microsystem interfaced to a Bolt Beranek and Newman (BBN) SpaceGraph volumetric display. Included in the existing baseline were software packages associated with these systems and selected demonstration capabilities. Figure 2.3-1 lists the major components of the Silicon Graphics based system, and Figure 2.3-2 lists the major components of the Z-248 based system.

The baseline ACCE configuration was primarily used as a demonstration environment for advanced display and presentation technology. The two applications demonstrated most frequently were the MITRE 3D Display for Battle Management prototype and the BBN SpaceGraph volumetric demonstration.

Hardware Resources	Silicon Graphics IRIS 4D/70GT Workstation (8 MB memory)
	Stereographics LCSS Z Screen
	380 MB Hard Disk Storage and 170 MB Hard Disk Storage
	60 MB Cartridge Tape Drive
	3 Button Mouse
	Dials and Buttons Box
	Silicon Graphics Keyboard
	Summagraphics Digitizer with 4 Button Mouse
System Software	IRIX Operating System (Unix) and Utilities
Support Software	C Compiler
	Silicon Graphics 4D Gifts Software and C Source Code
	Unix Ethernet Software
Interfaces	Ethernet LAN Interface, 10 Serial Interfaces
	Hayes 2400 Baud Modem
Data Base	None
Application Software	MITRE 3D Display for Battle Management Program Software and Source Code. SCENARIO Developed by IIT Research Institute.

ACCE Silicon Graphics/Stereographics System Resources
Figure 2.3-1

Hardware Resources	Zenith Z-248 (512 KB of memory)
	BBN SpaceGraph Volumetric Display
	EGA and Color Monitor
	Z-248 Keyboard
	Microsoft Mouse
System Software	Zenith DOS Version 3.0
Support Software	Turbo C Compiler
	EMACS and DOS Line Editors
Interfaces	3COM Ethernet Interface
	Serial and Parallel Interfaces
Data Bases	None
Application Software	BBN SpaceGraph Volumetric Demonstration Program

ACCE Z-248/SpaceGraph Volumetric System Resources
Figure 2.3-2

Overall, the baseline ACCE configuration was found to provide an adequate point of departure for future ACCE enhancements and implementation. The baseline ACCE systems provided the ACCE project team with an assortment of system capabilities and implementation approaches that subsequently were exploited to demonstrate advanced 3D display and user input devices and techniques.

Of the two major systems in the ACCE baseline, the Silicon Graphics system was certainly the most significant. The workstation has the capability to act as the centralized graphics engine and control point for simulations using more than one device. The system can be upgraded through the addition of processors and memory to support graphically intense operations. The display, when not operating in 3D mode, provides a good baseline to compare high quality color 2D displays. When operated in 3D mode in conjunction with appropriately developed software, the Stereographics Z-Screen provides an advanced display capability suitable for demonstration and evaluation. This type of display is innovative and is not generally found in the operational C2 world. The software on the system provides a quality development environment to support implementation and demonstration of evaluation prototypes. The software suite is in general compliance with industry accepted standards for operating systems, network interface and development languages. The 3D Display for Battle Management software is a useful simulation that matches ACCE technology with a C2 problem and provides an objective demonstration of 3D display technology.

On the other hand, the Z-248 was found to be best used as a system dedicated to controlling the SpaceGraph volumetric display. It could also provide, for comparison operations, a medium resolution color display representative of current IBM PC/DOS based platforms.

The assessment found that the capability of ACCE demonstrations to show the potential solution of C2 relevant problems needed to be improved. The 3D Displays for Battle Management simulation provided a quality demonstration that was operationally relevant, but association of the Z-248/SpaceGraph volumetric display's capabilities to operationally relevant C2 problems was, to a large extent, left up to the viewer.

The baseline ACCE configuration concentrated on the demonstration and evaluation of 3D display and user input devices. The comparison of 2D or 2 1/2D (software-generated perspectives/views) to true 3D (e.g., stereographic, volumetric, holographic, etc.) is neither easy, nor direct. Since the Stereographics and Z-248/SpaceGraph volumetric displays represented competing 3D display technologies, it would be valuable to be able to view both these devices in a single simulation. This would allow the ACCE staff to directly compare and assess their relative strengths and weaknesses.

A number of different user input devices were included in the baseline ACCE along with the more conventional mouse and keyboard devices. Future prototypes needed to be developed to evaluate the non-standard devices and assess how they might be useful.

Finally, with the exception of the Ethernet interface, the Z-248/SpaceGraph volumetric system is not compliant with either the industry accepted standards for the operating system (Unix), or the user interface (X-Windows). Therefore, the assessment indicated that the ACCE needed to provide developers with a programming language, such as "C", that would be compatible for controlling both the Z-248 running DOS and Silicon Graphics system running Unix.

In summary, the baseline ACCE provided a good foundation, but a number of technology and demonstration shortcomings were found. For example, the assessment found that the ACCE needs to include other types of display and presentation technologies. The hardware and software components of the baseline ACCE focused only on advanced 3D display technology and user input devices. Other major technological thrusts under the broad area of display and presentation technology need to be assessed in the ACCE. These include technologies such as multimedia presentations, large screen 3D presentations and simulations, virtual reality simulations, and large screen displays. Such technologies are innovative and offer potential payoffs for improving the understanding and solution of C2 problems.

2.3.2 ACCE Open System Architecture

An Open System Architecture (OSA) is a computer system organization that allows software functions and hardware to be added or deleted without changing the underlying framework. This architecture can be achieved in part by adhering to structured design methodologies that result in modular systems having well defined functions and interfaces. Other OSA considerations are adherence to standards regarding the development language, computer operating system, communications methodology, data base and human machine interface.

The following highlight the primary characteristics of an OSA. The reference sources were the IDHS Architecture Newsletters published by the Air Force Intelligence Agency (1 April 1989 through 30 November 1990) and the TAF Unit-Level Open System Architecture Specification, dated 21 September 1990.

- **Interoperability**: The ability to provide and accept data or services from another computer system.
- **Portability**: The capability of software developed on one hardware platform to be moved or ported to other hardware platforms and reused.
- **Commonality**: This feature allows users to access in a consistent manner, diverse computer systems having different characteristics. Normally this is accomplished by using

standard HMI features to present users with a common look and feel across diverse systems and applications.

- **Extensibility**: The ability to increase the scope of an architecture. This allows for the addition of more hardware platforms to a particular site, or for the inclusion of new software functionality to gain added capability.

- **Scaleability**: The ability to expand the capabilities of a single component of a system by adding increased functionality or increasing its performance to accommodate growth.

- **Remote Operation**: This feature allows system users to take advantage of resources that are available, but not collocated with the user.

These desired characteristics are obtained through the prudent use of recognized systems standards that promote hardware independence, software portability, and application interoperability. These standards are applicable to the various components of any computer architecture. For the ACCE, the following OSA standards were evaluated to determine whether they should apply:

- **Computer Operating Systems**: The use of "POSIX" or "Unix" compliant operating systems that can be called in a standard manner.

- **User Interfaces**: The use of "X-Windows" based window managers for computer screens.

- **Network Management**: The use of industry and government accepted TCP/IP, NFS, and/or GOSIP standard communication protocols.

- **Data Bases**: The use of SQL, an industry accepted data base manipulation language, to be used by software applications that communicate with a data base management system (DBMS).

The creation of an open environment is an important objective in the design of ACCE resident prototypes. Because ACCE is to be an advanced demonstration and evaluation environment, it will include state-of-the-art, sometimes non-standardized, display and presentation technologies. Without the application of sound system development techniques and the use of industry and DoD accepted standards whenever possible, the ACCE could easily become a hodgepodge of advanced technologies that fails to function as a cohesive environment. The OSA helps to mitigate these risks.

The following sections discuss various open system architecture related recommendations for design of the ACCE. These recommendations temper the guidelines and standards comprising the USAF OSA model with the objectives, operational requirements, and constraints of the ACCE as stated in the ACCE Concept of Operations.

- **Computer Operating System**: It was recommended that the primary operating system to be used within the ACCE be Unix. By adhering to this standard through the choice of Unix, adherence to other standards for communications, user interface, and data base interface standards come more naturally since TCP/IP, X-Windows, and SQL are defacto standards for communications, windowing systems, and DBMSs running under the Unix operating system.

- **User Interface Recommendations:** The use of the X-windowing HMI system was recommended for future development within the ACCE. It must also be noted however, that the very nature of the ACCE, as the environment developed to evaluate the cutting edge of display/and HMI technology, may necessitate deviation from the X-Windows standard. The use of new and innovative display and HMI devices may require the use of specialized windowing and graphics functions, functions that are new and thus have not yet become part of industry accepted windowing standards. To resolve possible difficulties introduced by non-standard interfaces in state-of-the-art technology, it was further recommended that software layering techniques be utilized to separate software into device independent and device dependent operations. As a result, at least the device independent functionality can be ported to other platforms.

- **Network Management**: It was recommended that the TCP/IP communication protocol be used whenever possible. The use of TCP/IP and other OSA compatible protocols such as NFS, and/or GOSIP should be a realizable objective since most of the devices in the ACCE hardware environment are envisioned to be predominantly Unix-based and therefore will include TCP/IP (and to a lesser extent NFS) communications facilities as part of the operating system. OSA compatible communications with devices and data sources external to the ACCE should also be achievable since many of the operational Air Force systems are already TCP/IP and, to a lesser extent NFS compliant.

- **Data Base**: Data base choices probably can be deferred for the near and mid-term development phase. This is because the ACCE focuses on the integration, evaluation, and demonstration of display and presentation technology, and in most cases the data bases used within ACCE will be simulated. It is envisioned that as ACCE grows in the future, it may become necessary to utilize a DBMS to manage and access large simulated data bases that may be necessary to drive large ACCE simulations. DBMSs and data base interfaces will have to be examined at that time to ensure that they are compatible with the ACCE's OSA specified standards.

2.3.3 ACCE Architecture

This section provides a description of the ACCE architecture that was developed during this task, and the ACCE Display Evaluation Prototype (demonstration prototype), a prototype that was

developed to run on the architecture. The objectives of the ACCE architecture and prototype designs were twofold:

- To expand on the ACCE baseline configuration and to create an ACCE open system architecture capable of supporting the demonstration and evaluation of advanced display and presentation technology.

- To implement an evaluation prototype within the ACCE that demonstrates advanced display technology applied to a C2 problem and validates the overall utility of the ACCE as an aid to research and development.

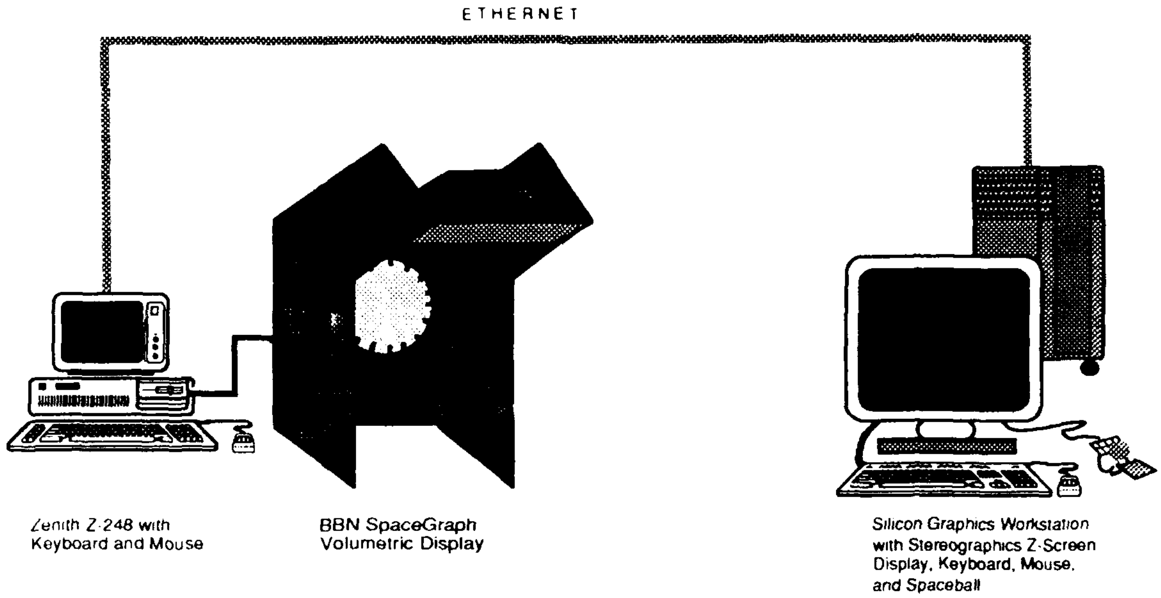
From the baseline assessment, it was determined that sufficient advanced 3D display technology existed in the ACCE to warrant design and implementation of an architecture and a demonstration prototype. The first step in the development of the ACCE prototype involved the selection of an operational C2 scenario that demonstrated advanced display and presentation technology. Several current research and development programs were examined as potential sources of a simulation scenario for the application of 3D display technology. Of these programs, the scenario addressed by the Air Defense Initiative (ADI) program was selected. Within the broad ADI thrust, a specific prototype, the ADI Simulation for Command and Control, or ADISC2 project, was identified as containing specific display scenarios that would benefit from the application of 3D display technology. The objective of ADISC2 was to develop an integrated simulation to provide threat, surveillance, engagement and communications models that can be exercised according to approved scenarios.

The ADISC2 program had three characteristics that made it an ideal candidate for the application of advanced 3D display technology. First, the ADISC2 program is currently under development. It is mature enough to provide example displays and scenarios that can be simulated using 3D display technology, but is early enough in its development cycle so as to be able to benefit from 3D display technology if the prototype proves that the technology is promising. Second, the system's displays make extensive use of computer graphics that are complex, dynamic and visually interesting. Finally, the displays portray objects that possess three dimensional geometries. The earth, as well as over-the-horizon (OTH) and space based radar areas of coverage are three dimensional volumes that are currently depicted as two dimensional objects only because of limitations in the ADISC2 display technology. It was determined that ACCE experimentation could be conducted to gauge the benefits of applying advanced 3D display technology to an ADISC2-like problem.

2.3.3.1 Hardware Architecture

To support the development of an advanced display and presentation prototype, a generic hardware and software architecture was developed within the ACCE. The hardware architecture for the prototype is shown in Figure 2.3-3 and consists of the Silicon Graphic/Stereographic Z-

Screen display system, the BBN Z-248/SpaceGraph volumetric display system and each system's respective hardware and software components as described in Figures 2.3-1 and 2.3-2. The two systems were interfaced to each other via an Ethernet connection.



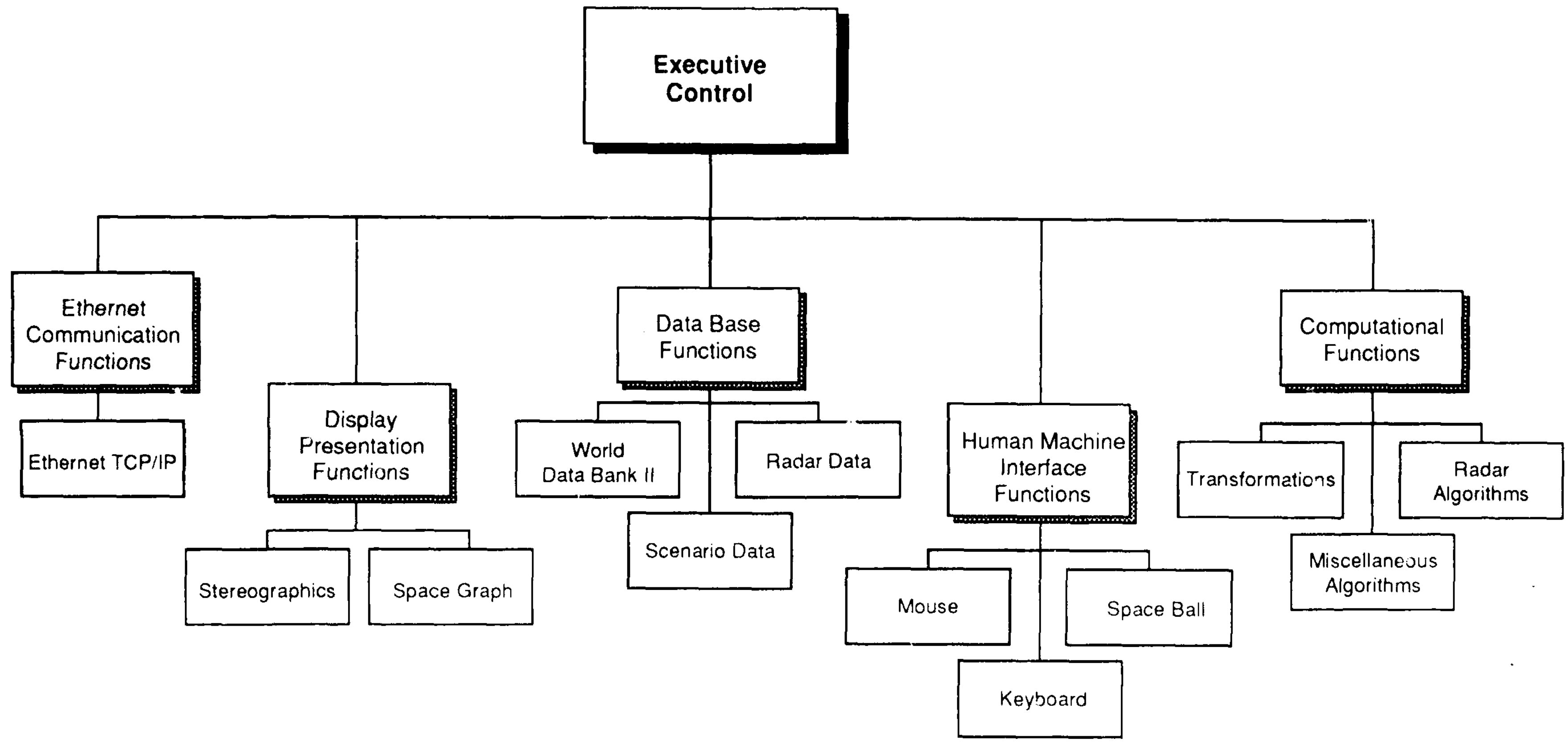
Hardware Architecture for Demonstration Prototype
Figure 2.3-3

Various upgrade and enhancements were performed on this architecture to support the demonstration of advanced display and presentation technology, and specifically, advanced 3D display technology. These upgrades included the addition of 8 MB of memory to the Silicon Graphics 4D/70GT workstation bringing the total memory to 16 MB, addition of a 700 MB hard disk drive that brought the total hard disk storage capacity to 1080 MB, and the addition of a six axis Spaceball user input device to the Silicon Graphics configuration. This device was selected to provide a very intuitive means of manipulating the objects displayed in 3D. By twisting the ball, the user is able to directly input rotation and translation commands in three dimensions.

2.3.3.2 Software Architecture

The software architecture that was developed to support the demonstration prototype is depicted in Figure 2.3-4. These functions include processes to:

- Provide executive software to control the overall execution of the prototype.
- Communicate display information between the SGI/Stereographic System and the Z-248/SpaceGraph volumetric display system.
- Display graphic information in 2 1/2D and 3D on the ACCE Silicon Graphic/Stereographic display System and the Z-248/SpaceGraph volumetric display system.



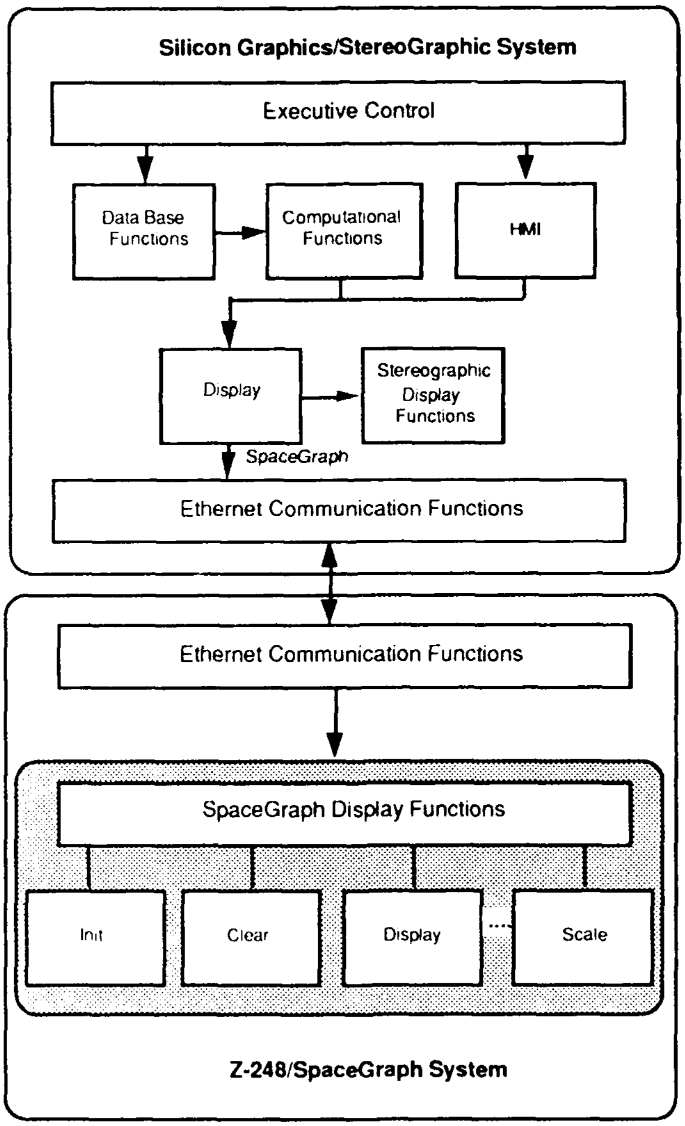
Software Architecture for Demonstration Prototype
Figure 2.3-4

- Perform data base manipulation operations on World Data Bank II derived map data, radar and scenario data bases.

- Provide HMI tools to control the operations of the prototype via 2D, 3D and keyboard devices.

- Provide computational functions in the form of geographic coordinate transformations, radar algorithms and miscellaneous mathematical operations.

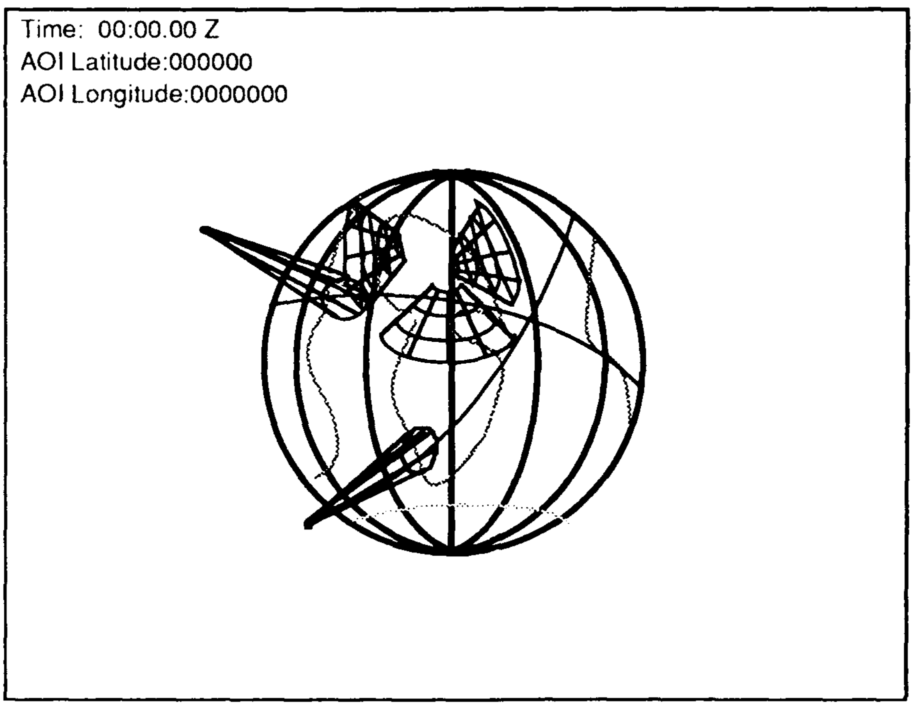
The executive software controls the execution of the prototype. Figure 2.3-5 depicts the functional flow that is controlled by this executive.



Demonstration Prototype Functional Flow
Figure 2.3-5

The flow commences on the Silicon Graphics/Stereographic System and, if required, is passed to the Z-248/SpaceGraph volumetric system. Once activated, the prototype initializes all values needed for processing including parameters for the computational functions. Next, it initializes all devices used within the operations including the Ethernet communication device if required, display devices (Stereographic Z-Screen and SpaceGraph volumetric via communication), mouse and 3D Spaceball. It then opens and reads the Scenario data base, WDB II data base, and the radar data bases. The prototype then graphically displays a world globe using the WDB II information via software commands to the WDB II data base, computational functions and display functions. If any radar data types are to be displayed, radar functions are processed to generate display directives for their respective area of coverage. Next, the executive waits for the user to provide direction via one of the user input devices. The executive function processes user input to generate and update the display presentation. For example, if the user selects a new geographic area of interest using the Spaceball, the Globe and radar display information are regenerated and displayed to reflect the new area of interest (AOI) position.

The prototype displays a line drawing of the world globe that is displayed on the SGI workstation in 2 1/2D similar to that shown in Figure 2.3-6. Overlaying this globe are wireframe volumes representing space based radar (cone shapes) and over-the-horizon (fan shapes) areas of coverage. The parameters that define the number and characteristics of the radars in the simulation are read during run time from editable text files.



Sample Prototype Display
Figure 2.3-6

In the upper left corner of this display, a digital clock is shown describing the simulated time of the prototype and the center latitude and longitude coordinate of the current AOI. The prototype display is animated in two ways. First, the space based radars are dynamic objects that move around the globe along a designated path as time progresses. Also the user can dynamically rotate the entire globe and its associated radars by manipulating the Spaceball user input device.

Once the simulation is started, the user can then control and manipulate the simulation by using a collection of menu based functions and programmed Spaceball functions. Specific details regarding the menu functions and spaceball functions that are used to manipulate the simulation are provided in the Planning Framework Document included as Volume III of this report.

2.3.4 ACCE Development Plan

This chapter outlines the development plan to incrementally expand the ACCE baseline. The plan includes a variety of enhancements that have already been performed on the baseline ACCE configuration described in Section 2.3.1, as well as a series of proposed future tasks that are organized into time phased development roadmap.

Plans for future ACCE growth are based on two primary assumptions. First, major advancements and innovations in display and presentation technology will continue to occur over the next five to ten years. This is believed to be a fair assumption based on a preliminary examination of evolving technologies such as multimedia presentations, interactive presentations, and virtual reality simulations. While these technologies are still in their infancy, they promise to provide great advancements in knowledge visualization, and thereby will convey substantive and meaningful information to a viewer. Second, it is assumed that future funding levels, for both the ACCE, and the C2 programs that can potentially benefit from ACCE demonstrations, will continue near the present level. Both are necessary conditions for the continued success of the ACCE.

2.3.4.1 Baseline Enhancements

The primary enhancement that was performed on the baseline configuration involved the development of the demonstration prototype described in the previous section. This prototype showcases the advanced 3D display technology existing in the ACCE. Using the demonstration prototype, a user could directly compare 2 1/2D to 3D display technology, and 3D to competing 3D display technologies in an user interactive C2 significant simulation. The simulation is controlled from a single point, the Silicon Graphics workstation, and is not scripted. This allows the user to interactively change various display characteristics as well as the position of the globe itself. The demonstration prototype also highlights the use of multiple input devices. The simulation is manipulated by three different devices: the Silicon Graphics keyboard; the Silicon Graphics 3 button mouse; and the Spaceball device. This demonstrates to visitors the characteristics of these various user input devices.

In addition to development of the demonstration prototype, a number of hardware and software upgrades were made to the original baseline ACCE. These additions to the environment were necessary to support prototype development, evaluation and demonstration, and included:

- **The Silicon Graphics Workstation Upgrade.** The 4D/70GT Silicon Graphics workstation was upgraded to a Silicon Graphics 340/VGX. This upgrade significantly improved system performance, memory capacities, and hard disk storage capacities of the Silicon Graphics workstation.

- **The Z-248 Workstation Upgrade.** The Z-248 received both a hardware and software upgrade. The upgrade consisted of the following items:

Hardware	Software
New Basic Input/Output System Controller	MS-DOS v3.3
1 x 1.2 MB 5 1/4" Floppy Disk Drive	Microsoft C Compiler v6.0
1 x 1.44 MB 3 1/2" Floppy Disk Drive	
1 x 40 MB Internal Hard Disk	

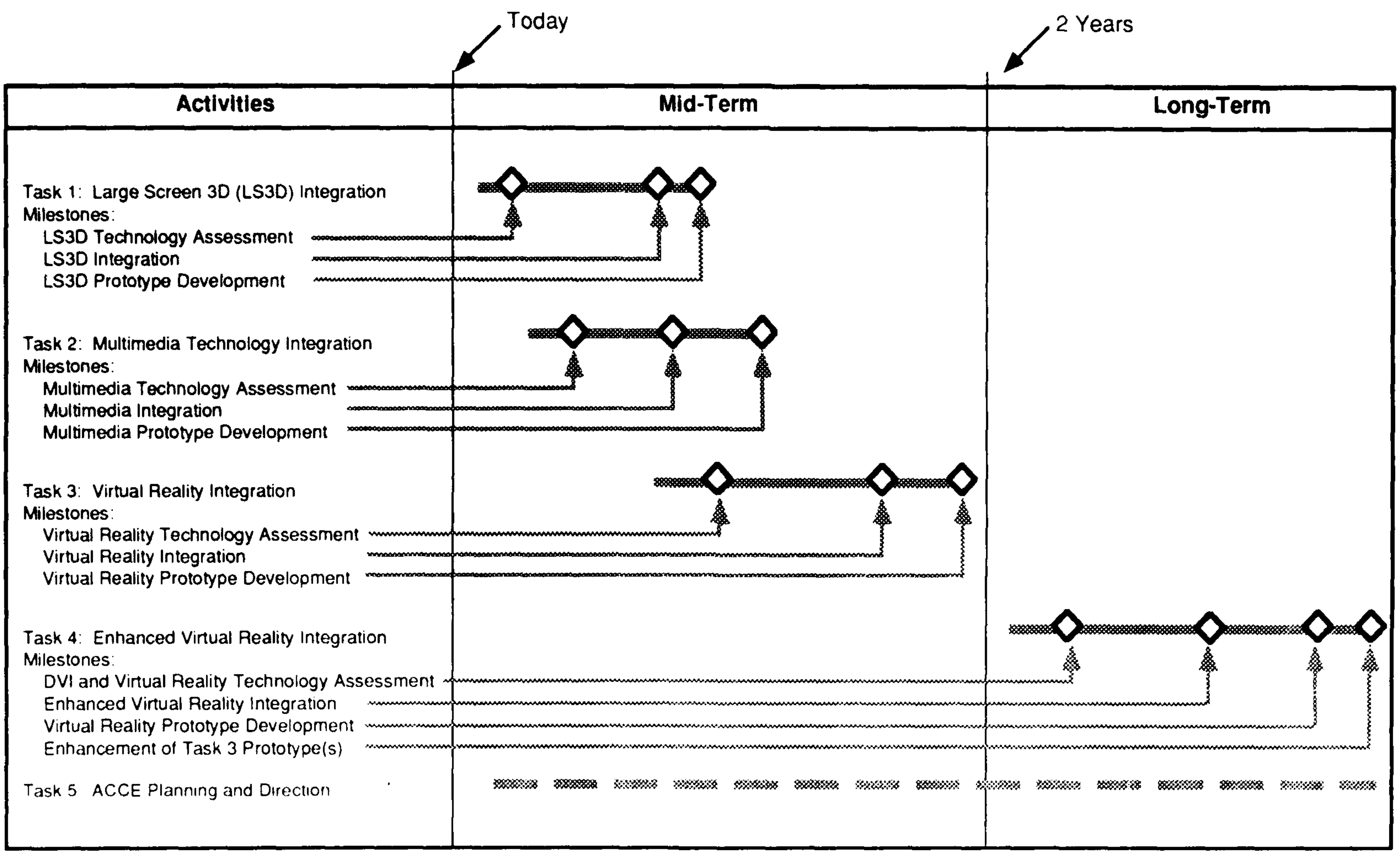
- **The Development of a Communications Interface between the Silicon Graphics Workstation and the Z-248 Workstation.** This interface was developed to support the creation of integrated cross platform prototypes.

- **The Addition of Two X-Terminals.** These terminals allow multiple developers to operate on the ACCE local area network and simultaneously access the Silicon Graphics Workstation.

These added tools, libraries, and interfaces made development within the ACCE easier and more efficient. Also, since it is generally true that a better development environment produces better systems, these additions resulted in smoother running, more efficient demonstrations that were faster and easier to develop and modify.

2.3.4.2 Future Enhancements

The following tasks were nominated to direct the development of the ACCE in the years to come. A roadmap for future ACCE development is presented in Figure 2.3-7. This roadmap addresses the schedule and the milestones for enhancements to the environment.



ACCE Development Roadmap
Figure 2.3-7

Task 1: Large Screen 3D Integration

The objective of this task is to integrate large screen 3D display technology into the ACCE and to develop and demonstrate the technology's ability to better solve C2 problems. A sub-objective within this task will be to compare and contrast the resulting large screen 3D capability with small screen 3D capabilities, as well as with conventional large screen 2D capabilities.

The Large Screen 3D Integration task is relatively short in duration, probably less than a year, and will be able to occur very early in the mid-term development phase due to the maturity and availability of underlying technologies. Its major milestones involve completion of the large screen 3D technology assessment, integration of a generic large screen 3D display capability, and implementation of demonstration prototypes.

Task 2: Multimedia Technology Integration

The objective of this task is to integrate Multimedia technology into the ACCE and to develop and demonstrate the technology's capability to better solve C2 problems. Though multimedia is likely to be the most near-term technology nominated for future ACCE tasks, it may also be the technology area that offers the most benefit to the C2 problem solving process. The technology appears especially applicable for use in C2 knowledge visualization, creating softcopy briefings and preparing advanced automated training aids.

The Multimedia Technology Integration task is similar in duration to Task 1. It is scheduled to start slightly later than Task 1 to decrease contention for valuable ACCE development resources. Its major milestones involve completion of the multimedia technology assessment, integration of a generic multimedia system platform, and implementation of demonstration prototypes.

Task 3: Virtual Reality Integration

The objective of this task is to integrate virtual reality technology into the ACCE and to develop and demonstrate the technology's capability to better solve C2 problems. The virtual world used by current systems consists exclusively of a computer generated model. Algorithms that sense inputs from the viewer are used to determine the viewer's position and viewing direction within the model. Based on these inputs, computer generated images are rendered from the 3D model to provide images as seen by the viewer.

The Virtual Reality Integration task is a more involved development task. It will therefore be longer in duration, probably more than a year. Task 3 is also scheduled to begin later in the mid-term development phase than tasks 1 and 2. This later start will allow time for the relatively immature technology to progress before integration into the ACCE begins. Its major milestones involve

completion of the virtual reality technology assessment, integration of a generic virtual reality system platform, and implementation of any operationally relevant virtual reality prototypes.

Task 4: Enhanced Virtual Reality Integration

The objective of this task is to improve upon the basic virtual reality capability developed in Task 3, and to demonstrate the technology's capability to better solve C2 problems. The task will concentrate on improving the degree of realism achievable in virtual reality simulations possibly by using digital video interactive (DVI) in the virtual reality simulation, as well as newly developed, innovative display and user input technology that may be available.

The Enhanced Virtual Reality Integration task begins where Task 3 leaves off. Its duration will probably be more than a year. Its first milestone involves completion of a second virtual reality technology assessment that also includes the investigation of DVI technology. Following this, design and integration of an enhanced virtual reality system platform will be performed. This effort may significantly augment the platform developed within Task 3. Implementation of new, operationally relevant virtual reality prototypes, as well as possible enhancement of the prototype(s) developed during Task 3 will then be completed.

Task 5: Planning and Direction

Tasks 1, 2, 3, and 4 can be grouped since they *all* involve the *investigation*, *integration and demonstration* of separate but related display and presentation technologies. They all possess the common goals of integrating advanced technology into the ACCE, demonstrating how the technology can be used to solve C2 problems, and aiding in the transition of promising technology into operational Air Force C2 systems. Since some of these tasks may be conducted simultaneously, there may also be contention for valuable ACCE hardware and software resources. For these reasons, this fifth task entitled, Planning and Direction, has been created to provide the management needed for the other ACCE tasks. By creating synergy among the four other tasks and reducing duplication of effort between them, better ACCE systems and prototypes can be produced with less overall effort. Specific activities within this task include:

- Assisting with the nomination and investigation of candidate C2 scenarios, problems and systems.
- Approving ACCE hardware and software additions and modifications.
- Scheduling and coordination of ACCE demonstrations.
- Scheduling and coordination of system upgrades and resource sharing.

The ACCE Planning and Direction task is shown as a dashed task bar. Since the goal of Task 5 is to oversee all development tasks, it will extend the entire length of the timeframe for future ACCE development. Also, since Task 5 is reactive in nature, it initially has no notable milestones.

2.3.5 ACCE Configuration Management

An important component of this planning framework activity involved the development of recommendations for the management of the ACCE configuration. These recommendations address the areas of configuration identification, and configuration control, as well as specifying the types of documentation that should be developed for and maintained within the ACCE.

First, it is recommended that a library be maintained that describes the many components of the ACCE configuration. This library would contain information describing the environment's components, contacts for sales, technical, and maintenance information, and a chronological record of the history of each component.

Second, it is recommended that formal procedures for configuration control be established. One suggested procedure involves the maintenance of two prototype software versions. One would be a demonstration version, and the second the development version that is actively modified, revised and enhanced during implementation of prototypes. Also, it is recommended that the decision making process for hardware and software configuration modifications be centralized and managed. Proposed enhancements to the ACCE configuration must be carefully evaluated to assess their potential impact on the ACCE as a whole. Such a procedure will allow ACCE developers to fully consider the ripple effects of a modification before it is implemented.

Finally, it is recommended that documentation on contractor delivered systems, platforms, and prototypes be maintained in the ACCE. This should include detailed hardware and software information like that contained in the Concept of Operations document (FTR Volume II), functional specifications, and design documents. Also documentation detailing the software architectures, functions and data bases should be created by the developers and maintained within the ACCE. This type of documentation will facilitate the reuse of existing software and data, a technique that is essential to help reduce implementation costs. Also, since the ACCE is a demonstration environment, documentation must be maintained that describes the demonstration procedure for each prototype. This documentation would contain the steps an operator would take to execute the prototype to showcase its capabilities.

Chapter 3

Conclusions and Recommendations

3.1 Conclusions

A number of conclusions can be drawn regarding the overall value of the ACCE based on the conduct of the ACCE Integration contract, and the accomplishments embodied in the ACCE Concept of Operations and the ACCE Planning Framework documents. These conclusions and related recommendations are provided in this chapter.

3.1.1 The ACCE

The ACCE provides an open environment that fosters technology integration and experimentation without the constraints, schedules, and strict requirements associated with the development of a system directly earmarked for the field. As such, the ACCE can act as an intermediary between the advanced technology development laboratory and operational Air Force systems. The environment provides a means to bring together the technologist, concerned with developing and improving technology, and the C2 user and system developer, concerned with efficiently solving Air Force command and control problems.

Use of the ACCE lowers the overall risk and cost associated with integrating advanced technology directly into system development efforts. The ACCE gives users, managers, and developers a first-look at newly emerging advanced technologies in operationally relevant scenarios. Based on ACCE evaluations, recommendations can be made on how to improve technology to make it more useful to Air Force command and control problems. These evaluations also allow Rome Laboratory system developers and project managers to make educated choices about which advanced technologies to pursue and include in future system development efforts.

3.1.2 The ACCE Concept of Operations (CONOPS)

A major accomplishment of this contract involved the development of the ACCE CONOPS. This document formally defined what the ACCE is, how it will be used, and by whom it will be used. Included in the CONOPS are procedures that describe how the ACCE will work in concert with the C2TC to use advanced technology in operationally relevant scenarios to produce better operational systems for the Air Force. The CONOPS also stated a list of goals for the ACCE. These goals provide a yardstick to measure proposed future ACCE developments and assess technology developments outside of the ACCE. Though formal, the CONOPS is not meant to be

a rigid specification. As Air Force requirements change and new technologies develop, it will likely be necessary to revise and update the ACCE CONOPS to reflect the new visions.

3.1.3 The ACCE Planning Framework

Development of the various components of the ACCE Planning Framework documentation was also significant. The Planning Framework assessed the state of the ACCE configuration as it existed at the start of the task, documented significant enhancements to the configuration made during the task, and proposed future research and development efforts beyond this task to ensure the ACCE's continued growth. Three emerging technologies were identified as having potential C2 application. These technologies are large screen 3D, multimedia presentations and virtual reality.

Of the three technologies listed in the Planning Framework roadmap, we concluded that virtual reality is both the most risky, but potentially the most significant technology. Virtual reality systems could revolutionize the concept of simulation and human perception by creating computer-simulated experiences that are undiscernible from reality. In many respects the capabilities of virtual reality simulation may in fact add value to actual reality. For instance, it is often desirable to run simulations repeatedly to test what-if situations. Virtual reality devices would allow one to display information that isn't perceivable in reality, such as radar cross sections, threat envelopes, or terrain and weather models.

3.1.4 Demonstration Prototype Technology Evaluation

The many enhancements that were incorporated during the task resulted in the establishment of a robust hardware and software configuration suitable for the development of ACCE display and presentation prototypes. In fact, one such demonstration prototype was developed to show the new 3D display technology in a C2 relevant setting and thereby aid in its evaluation. This prototype was developed in the ACCE, for the ACCE, and according to the ACCE task flow presented in the Concept of Operations. This successful application of the ACCE procedures helped to verify and refine the CONOPS. Advanced display/user input devices used in the prototype and evaluated during this task included the Silicon Graphics 340/VGX workstation, the BBN SpaceGraph Volumetric Display, the 3D Spaceball input device, and the Stereographics Z-Screen Display.

The following provides selected conclusions pertinent to the major hardware/software components available in the ACCE.

3.1.4.1 The Silicon Graphics 340/VGX

The Silicon Graphics 340/VGX is the primary workstation configuration in the demonstration prototype and is highly recommended for use in future ACCE development activities Though

not an advanced experimental technology in the sense of the Stereographics Z-screen or BBN SpaceGraph display, the Silicon Graphics 340/VGX is a high performance workstation that is representative of today's most advanced, commercially available graphics workstations. The 340/VGX includes a full suite of specialized high-performance graphics and display hardware that can portray graphically complex simulations and prototypes. To further support prototype development, the workstation provides a software suite that includes an intuitive program editor, as well as a full range of development languages and utilities. The 4D Gifts application and its source code, supplied by Silicon Graphics, gives the ACCE a significant collection of sample programs, utilities and demonstrations to assist in the development of new customized graphic applications.

3.1.4.2 The BBN SpaceGraph

Though interesting, the BBN SpaceGraph display is not recommended as a technology that is suitable for use in operational Air Force systems. The SpaceGraph is big, bulky, and somewhat unreliable. Moreover, the SpaceGraph does not provide a color display capability. Color is an expected feature of current workstation based systems because it helps viewers to better understand visually complex displays. Also, when a 3D data representation is rendered for display on the SpaceGraph, some fidelity of the picture is lost due to limitations imposed by the display hardware. In addition, the SpaceGraph rendering process is time consuming making the display device impractical for use in dynamic, animated 3D simulations. Finally, detailed documentation describing how to use the SpaceGraph in custom applications is not available. Developers need to possess this type of information to incorporate non-standard, exotic devices like the SpaceGraph display in their simulations.

On the plus side, the display does provide a very good 3D viewing effect. This effect can be perceived from a wide range of distances and viewing angles without the aid of special glasses. Though providing some enhanced 3D display functionality, the following enhancements are recommended before this technology will be viable for operational C2 systems:

- Addition of color display capabilities.
- Addition/improvement of specialized hardware for faster rendering, better fidelity, and improved reliability.
- Better documentation.

3.1.4.3 The 3D Spaceball

The 3D Spaceball user input device proved to be an excellent device for manipulating 2 1/2D and 3D displays. Its use is strongly recommended in future development efforts involving 3D image manipulation. The device is responsive, easy to use, and provides a natural means to input 3D rotation and translation commands. Programming the device is easy, straightforward and quick. In

addition, there are eight special keys located at the top of the Spaceball device that allows you to program frequently used functions.

3.1.4.4 The Stereographics Z-Screen Device

The Stereographics Z-Screen device was found to be suitable for use in Air Force system prototypes. The Stereographics Z-screen is reliable, and relatively easy to use and program. The development of Z-screen software was expedited through the use of examples and source code provided by the device manufacturer. The images displayed on the Z-screen are in color, and can be viewed in either a stereo or non-stereo mode. When viewed in the stereo mode, properly rendered images could be seen in 3D with the use of polarized glasses. The Stereographics Z-Screen device also integrated well into the underlying Silicon Graphics workstation architecture. This allowed the hardware-based graphics power of the workstation to be harnessed for Z-screen 3D displays.

There are some limitations to using the Stereographics Z-Screen. For example, to perceive a 3D effect, the viewer must be positioned the proper distance away from the screen and directly in front of it. This is a limitation of the underlying stereoscopic process, and not the Z-screen device itself. Second, the perception of 3D is negatively impacted by some stereoscopic bleed-through. Bleed-through is a stereoscopic phenomenon whereby the left and right lenses of the polarized glasses do *not* totally block out the right and left stereo display images, respectively. The result is a shadowing effect that causes each eye to perceive not only the stereo image that is intended for it, but also a degraded version of the image intended for the other eye. The bleed-through phenomenon probably can be eliminated if one uses newer stereo viewing glasses (Stereographics Crystal Eyes) that have active LCDs to block the opposite eye's image instead of the polarized lenses that were available during the evaluation.

3.2 Recommendations

The ACCE is, and should continue to be, an integral part of the command and control system development process. Its goal should be to adapt new and innovative display and presentation technologies to the changing requirements of the Air Force command and control process. To do so, a number of recommendations for the future development of the ACCE are provided.

1. **Start new ACCE technology evaluations.** To continue the momentum achieved in this initial ACCE task, it is recommended that new ACCE technology evaluations be started within six months after the conclusion of the current task. The selection of specific advanced technology components, such as large screen 3D displays, multimedia, and virtual reality that can easily be integrated into the ACCE, will be important. The roadmap in the Planning Framework document (FTR Volume III) provides a recommended course of action for the new evaluations.

2. **Ensure that ACCE prototypes are operationally relevant.** ACCE researchers need to actively seek out information on future C2 problems that are interesting, challenging, and can benefit from the application of advanced display and presentation technology. The factor that differentiates ACCE from other technology development laboratories is its close connection with the C2 system user community. ACCE developers need to exploit this relationship early, by involving users prior to and during prototype development, as well as during the post-development evaluation and refinement phase.

3. **Demonstrate the ACCE technology.** The ACCE is an environment that will thrive on visibility. Its capabilities need to be marketed and actively demonstrated to a wide and diverse audience. These demonstrations will foster interest in the ACCE's technologies thus ensuring its legacy and value.

4. **Provide active management to ACCE technology integration efforts.** As the ACCE grows and becomes more complex, configuration management will become critical to control the hardware and software modifications that will be necessary. This includes giving careful consideration to the impact of technology acquisitions on current ACCE operations.

   Active management will also be required to select the best technology for evaluation. When trying to stay on the leading edge of technological developments, six month old technology is sometimes outdated. Thus, it is important to survey and acquire new technology immediately before the technology is to be evaluated. For this reason, technology integration efforts were proposed under the development plan that encompass the entire task flow concept developed for the ACCE. Each of the proposed efforts begin with an initial survey to identify the latest display and presentation technologies. Viable technologies will then be integrated into the ACCE and applied toward the solution of a specific C2-related problem. Then, as shown in the task flow diagram, post development demonstrations are required to support the transition of the technology to operational Air Force systems.

Appendix A

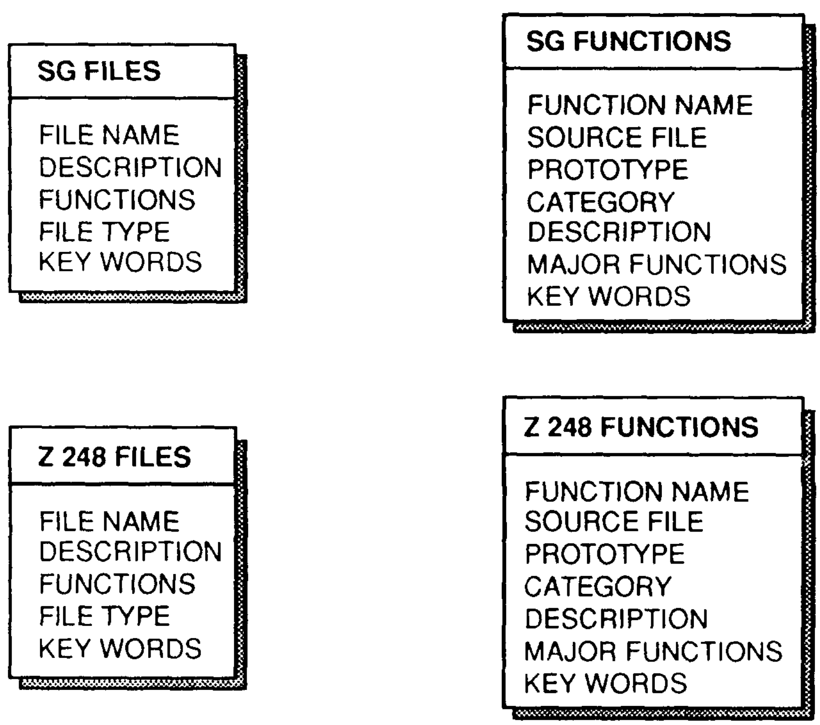
ACCE Software Library Data Base User Manual

A.1 Introduction

The ACCE Software Library Data Base was developed to organize the software documentation developed for the ACCE Display Evaluation Prototype (ADEP). The data base is implemented on a Macintosh workstation using the 4th Dimension Data Base Management System (DBMS) by ACIUS. The DBMS gives the user quick reference to the source code documentation describing the files and functions used in the prototype.

A.2 Organization

The data base organization for the ACCE Software Library is shown in Figure A.2-1.



ACCE Software Library Files
Figure A.2-1

The **SG Files** table contains a complete list of all ADEP software files located on the Silicon Graphics workstation. For each entry in this list, corresponding to an ADEP file, the following four data fields have been populated:

File Name:	The name of the ADEP file located on the Silicon Graphics workstation.
Description:	A brief description of the ADEP file's functionality.
Functions:	A list of major functions called from within the file.
File Type:	An identifier which tells if the file is a C-source code file, a header file or a data file.

The **Z-248 Files** table contains a complete list all the ADEP software files located on the Z-248 workstation. For each entry in this list, corresponding to an ADEP file, the following four data fields have been populated:

File Name:	The name of the ADEP file located on the Z-248 workstation.
Description:	A brief description of the ADEP file's functionality.
Functions:	A list of major functions called from within the file.
File Type:	An identifier which tells if the file is a C-source code file, a header file or a data file.

The **SG Functions** table contains a complete list of all ADEP software functions located on the Silicon Graphics workstation. For each entry in this list, corresponding to an ADEP function, the following seven data fields have been populated:

Function Name:	The name of the Silicon Graphics workstation resident function.
Source File:	The source code file where the function is defined.
Prototype:	The calling sequence for the function being described.
Category:	The general type of functionality that the function provides, for example: control, communication, computational, etc.
Description:	A brief description of the function.
Major Functions:	A list of the important functions which are called by this function.
Keywords:	A list of kevwords which describe the function's purpose. This list is provided to enable searching for functions addressing certain areas of functionality.

The **Z-248 Functions** table contains a complete list of all ADEP software functions located on the Z-248 workstation. For each entry in this list, corresponding to an ADEP function, the following seven data fields have been populated:

Function Name:	The name of the Z-248 workstation resident function.
Source File:	The source code file where the function is defined.
Prototype:	The calling sequence for the function being described.
Category:	The general type of functionality that the function provides, for example: control, communication, computational, etc.
Description:	A brief description of the function.
Major Functions:	A list of the important functions which are called by this function.
Keywords:	A list of keywords which describe the function's purpose. This list is provided to enable searching for functions addressing certain areas of functionality.

A.3 Functions

This section highlights basic user functions which are necessary to examine and query the software library data base. All of these functions are standard functions which are provided by 4th Dimension. Complete descriptions of these functions are provided in the 4th Dimension documentation provided by ACIUS.

- **Starting the software library data base**: The software library data base is started by positioning the cursor over the Icon or File named "**ACCE SW Library**" using the mouse, and clicking twice on the mouse button. The program will then initialize and display a brief welcome message.

- **Viewing data**: Following initialization, a display will appear which contains a list of data base entries similar to that shown in Figure A.3-1. The user can examine the entries in this list by scrolling through this list using the scroll bar located at the right edge of the display. To view detailed data about an entry in this list, the user positions the cursor over the desired entry and clicks twice on the mouse button.

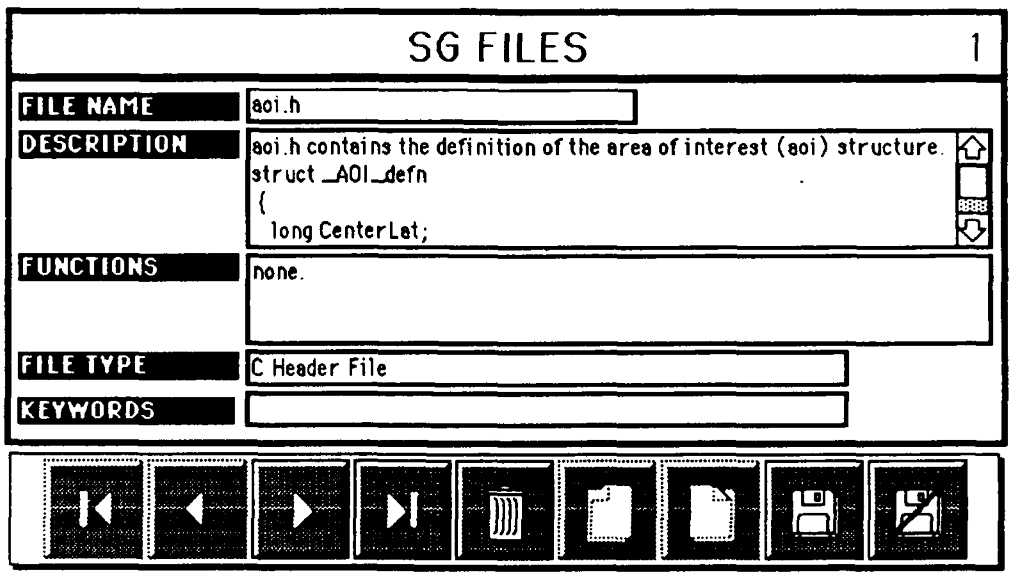
KSC ACCE

Data base containing documentation for the ACCE prototype.

FUNCTION NAME	CATEGORY	SOURCE FILE
init_demo()	Control	init_demo.c
InitializeSpaceball()	Control	init_demo.c
init_event_devices()	MMI	init_event_devices.c
main_event_loop()	Control	main_event_loop.c
menu_options()	MMI	menu_options.c
select_aoi()	MMI	select_aoi.c
conv_asc_2_latlon()	Computational	conv_asc_2_latlon.c
lat_lon_2_ascii()	Computational	lat_lon_2_ascii.c
set_default_parms()	Control	set_default_parms.c

Sample Output Layout
Figure A.3-1

As a result of this action, more detailed data will be displayed in a format similar to that shown in Figure A.3-2. The buttons located along the bottom of this display are used for browsing through the data entries, and for deleting, modifying, and saving the data base data being viewed. The rightmost button is the Cancel button and is used for exiting out of the detailed data display. All of these buttons are standard functions provided in the 4th Dimension DBMS. Each function is explained fully in the 4th Dimension User Guide supplied with the 4th Dimension DBMS.



Sample Input Layout
Figure A.3-2

- **Changing files and layouts**: As described in Section A.2 the data base is segmented into four distinct files. The data in each of these files can be viewed through one or more layouts. To list, view, and query data existing in these various files the user must change the current file which is being displayed. To do this, the user activates the **Choose File/Layout...** command under the **File** menu. The user then identifies the file and layout which is desired by positioning the cursor over the desired filename and clicking the mouse button twice; doing so expands the filename entry to show the layouts which are defined for that file. The user then positions the mouse button over either of the two layout names which are shown, and double clicks the mouse button. A list of the entries in the selected file or table will then be displayed.

- **Performing a query**: A major feature gained through the use of an automated DBMS is the ability to query the data in the data base. To query the data, the user activates the **Query Editor...** command under the **Select** menu. A query editor will then be displayed allowing the user to create a data base query. The user interactively builds a query by: 1) clicking on the desired data element name, 2) selecting the desired condition, and 3) by typing in the desired query string. Clicking the **OK** button in the query editor executes the current query. The standard functions provided in the 4th Dimension Query editor are explained fully in the 4th Dimension User Guide supplied with the 4th Dimension DBMS.

- **Help information**: To display descriptive help information while using the library data base the user selects the **About ACCE Software Library** command under the menu. Doing so displays a window containing text describing the ACCE Software Library. This text is scrollable using the scroll bar located at the right edge of the help text. To cancel the display of the help information and return back to the data base the user clicks the **OK** button located at the bottom center of the help screen.

- **Quitting**: To exit from the library data base the user selects the **Quit** command under the **File** menu. This command closes all open windows in the ACCE Software Library, and exits from the 4th Dimension DBMS Application.

Appendix B

Commercial-off-the-Shelf Manuals

KSC acquired the below listed commercial-off-the-shelf manuals and documentation and delivered them to RL/COA per ELIN V007, Contract F30602-87-D-0085/0020, ACCE Integration task. KSC did not modify this or any pre-existing ACCE documentation.

- Microsoft C, Advanced Programming Techniques,
  Copyright 1990, Microsoft Corporation.

- Microsoft C, Installing and Using the Professional Development System,
  Copyright 1990, Microsoft Corporation.

- MS-DOS Version 3.3 Plus, User's Guide and Command Reference,
  Copyright 1988, Zenith Data Systems.

- MS-DOS Version 3.3 Plus, User's Reference,
  Copyright 1988, Zenith Data Systems.

- 3+ Open TCP with Demand Protocol Architecture, Administration Guide,
  Copyright 1990, 3Com Corporation.

- 3+ Open TCP with Demand Protocol Architecture, Programmers Reference,
  Copyright 1990, 3Com Corporation.

- 3+ Open VT, User Guide,
  Copyright 1990, 3Com Corporation.

Appendix C

List of Acronyms

2 1/2D	Two and a Half Dimensional
3D	Three Dimensional
ACCE	Advanced Command and Control Environment
ADEP	ACCE Display Evaluation Prototype
ADI	Air Defense Initiative
ADISC2	Air Defense Initiative Simulation for Command and Control
AOI	Area of Interest
APS	Advanced Planning System
BBN	Bolt, Beranek and Newman Laboratories
C2	Command and Control
C2TC	Command and Control Technology Center
C3	Command, Control and Communications
C3I	Command Control Communications and Intelligence
CDRL	Contract Data Requirements List
CD-ROM	Compact Disk Read Only Memory
CO	Command and Control Directorate
COA	Applied Command and Control Systems Division
CONOPS	Concept of Operations
COTS	Commercial-off-the-Shelf Products

CPU	Central Processing Unit
CRT	Cathode Ray Tube
DBMS	Data Base Management System
DCA	Defense Communications Agency
DGZ	Desired Ground Zero's
DVI	Digital Video Interactive
EGA	Enhanced Graphics Adaptor
FTR	Final Technical Report
GOSIP	Government Open Systems Interconnect Profile
HMI	Human Machine Interface
KSC	Knowledge Systems Concepts, Inc.
LAN	Local Area Network
LCSS	Liquid Crystal Stereoscopic Shutter
MAD	Mutually Assured Destruction
MFLOPS	Millions of Floating Point Operations Per Second
MIPS	Millions of Instructions Per Second

OSA	Open System Architecture
OTH-B	Over the Horizon Backscatter
R&D	Research and Development
RL	Rome Laboratory
SAPE	Survivable Adaptive Planning Experiment
SGI	Silicon Graphics Incorporated
SIOP	Single Integrated Operational Plan
SOCC	Sector Operations Control Center
SON	Statements of Need
TACS	Tactical Air Control System
TRICOMS	Triad Computer System
VR	Virtual Reality

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